Basic Electrical Circuits

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Lecture - 38
Analysis of Circuits with a Single Independent Source

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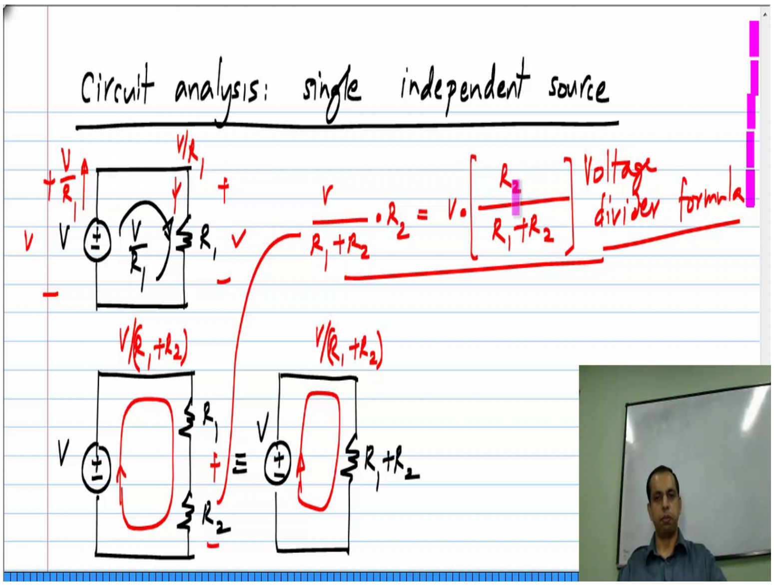

When you have a single independent source in a circuit; it turns out that there are ad hoc circuit techniques which you are probably already familiar with which will yield the solutions. This is why let say combining resistors and series and parallel finally, finding single equivalent resistance across the independent source and then solving for different variables after that. So, now we will first start from a really, really simple example and then work our way towards what is more complicated examples. Let us have a circuit like this an independent voltage source connected to resistor, even before I wrote down the circuit you know the answer the current is V by R 1. So, even if you wanted every variable in the circuit, you could tell that very easily the voltage across this is V. The current is V by R 1 in this direction the voltage here is V and the current is V by R 1 in that directions. So, you know that current and voltage across the two branches of the circuit which are the voltage source and the resistor.

Now, let say we had something like this we have voltage V connected to a series combination of a resistors R 1 and R 2. And again by reducing the series combination of resistors into a single resistor, you know that this is the same as that that single resistor R

1 plus R 2. Now the current through this can be easily solved for this voltage is V. So, in the current here is V by R 1 plus R 2 of course, that is the same current that is flow in the original circuit that is V by R 1 plus R 2. Now of course, you may be ask for anything you could be ask for this current in which case you already have it or you could be ask for this voltage, the voltage across R 2 which you can easily find by multiplying the current with the resistance value. So, the voltage across R 2 is nothing but V by R 1 plus R 2 which is the current times R 2 which is the voltage times R 2 by R 1 plus R 2.

Now, this is of course, the familiar voltage divider formula, which tells you that if you have a series combination of registers exited by voltage V, in the voltage across any single resistor is the ratio of that resistance to the total resistance of the series combination, times the applied voltage. So, we have resistance R 2 divided by the total resistance; in this case, we have only 2 resistors and that whole thing times the voltage V. So, this is the voltage divider formula. And if you wanted the voltage across R 1, you would have R 1 in the numerator of instead of R 2, so again very simple.

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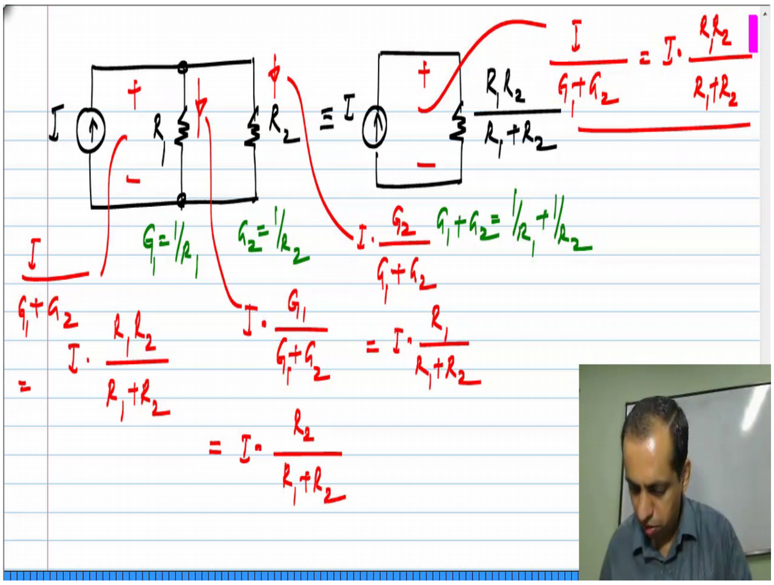

Now, let us take the case of let us say a current source connected to two resistors in parallel R 1 and R 2. So, again you know that this behaves as a current source applied to a single resistor now if you refer to each of these by their conductance G 1 which is 1 by R 1, and G 2 which is 1 by R 2. We know that the conductance of this resistance is G 1 plus G 2, which 1 by R 1 plus 1 by R 2. So, the resistance of the combination, we also know the formula is R 1 R 2 by R 1 plus R 2. We apply current I then the voltage that appears across this is simply this I times the resistance value or this I divided by the conductance value. So, this voltage is I divided by G 1 plus G 2, which is of course same as I times R 1 R 2 by R 1 plus R 2. So, some times when you have parallel combinations, it is useful to use conductance in the analysis then resistances. We should get use to both of them using either conductance or resistances. Now sometimes some of the expressions look simpler with conductance that with resistances, so that is the motivation for using them.

So obviously, the same voltage appears in the original circuit the voltage here is I divided by G 1 plus G 2 which is I times R 1 R 2 by R 1 plus R 2. Now you may be ask for this voltage in which case you have already solve for it or you could be ask for currents and individual resistors. So, this current is nothing but the voltage across this resistance divided by the resistance or the voltage across this resistance times the conductance value. You will write it in both forms. So, the current here is I times G 1 by G 1 plus G 2, basically it is this voltage times G 1, which is the conductance of this. And this can also of course, be written as I times R 2 by R 1 plus R 2, and this case I have taken this expression and divided it by R 1.

Similarly, the current through here is I times G 2 by G 1 plus G 2, which is also the same as I times R 1 by R 1 plus R 2. Of course, this is again the familiar current divider formula the voltage divides in proportion to resistances, the current divides in proportion to conductance. So, you see that in the voltage divider, we had R 1 by R 1 plus R 2' in the current divider we have G 1 by G 1 plus G 2 in the expression for the current through G 1. Normally, this is presented as ratio of resistors, in which case you to take the other resistor. And if you have multiple resistors, you have to take the parallel combination wall the other resistor. So for the current divider, the formula using the conductance is easier, but of course, you can use either of it. So, this is again another simple illustration.

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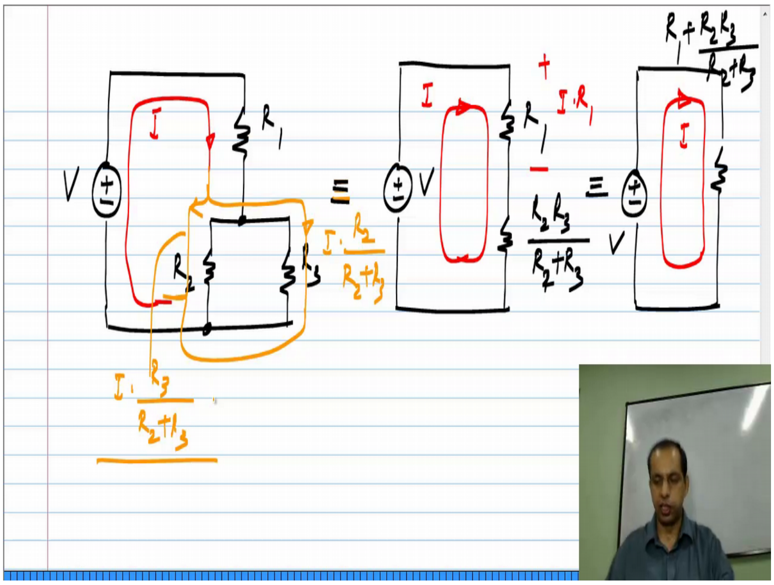

Next, we combine these 2 aspects together and form a circuit which looks like this. We have voltage V, resistance R 1, R 2, R 3 and this is the same as this R 2 and R 3 in parallel. So, we will have the parallel combination and R 1 we of course, finally, these were in series and can be reduced the single resistor. So, we can calculate everything from this that is first of all we can calculate the current I. So, this is the voltage V of course, I will be this V divided by the total resistance, and same I will be here and also here. And if you want to calculate the voltage across R 1, it will be I times R 1 which you can easily calculate.

Now, at this node, this I divide into two parts. So, some of it goes this way and some of it goes that way and finally, combined. And if you wanted these currents, the currents through R 2 plus R 3 and you can go back and use the current divider theorem. So, everything is some repeated combination of series and parallel elements. So, in that case you can use voltage divider or current divider accordingly and final solutions. For instance you already calculated I, so the current through R 3 would be I times R 2 by R 3 plus R 3. Let me put this in a different color. So, this is the current through R 3 and the current through R 2 of course would be I times R 3 by R 2 plus R 3.

So, now, the circuit can get the more complicated, but you can still go on using this. You can repeatedly apply these series parallel combinations and simplify to the picture single resistance across the independent voltage source and independent current source and find the current or voltage. And from there further calculate using higher voltage divider or current divider formulas. Now this works for many circuits, which have a single dependent voltage source.

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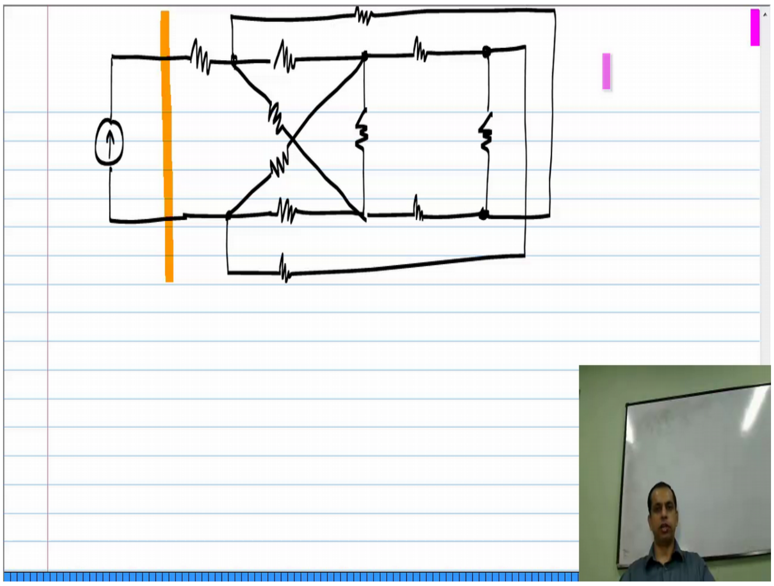

But things can get messy if you have let say things like this then even finding the equal and resistance that appears across the current source can involve the bit of analysis. So, in this case, it is probably better to just use the systematic analysis approaches. So, for instance, you can have even more complications. So, then even to find the resistance here you have the resort to systematic analysis approaches. So, you may as well find everything using systematic analysis. So, in summary, when you have a single independent source usually by looking at series parallel combinations in the circuit, you will be able to get a single equivalent element across the voltage or current source and from their progressively solve for everything you want.